ACIS Update

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The ACIS instrument continues to perform well and produce spectacular scientific results like the recent X-ray detection of the LIGO-discovered neutron star merger. This is reflected in the proposal statistics for Cycle 19 in which ACIS was five-times oversubscribed. There were no interruptions of scheduled observations due to ACIS anomalies in the past year and there are no instrument limitations on continued operation of ACIS indefinitely into the future. The calibration team continues to monitor the loss in QE due to the contamination layer and the charge transfer inefficiency due to radiation damage.

As the observatory ages, thermal blankets covering the surface continue to degrade, which tends to make many systems run hotter. This can be managed by careful mission planning, and in the case of ACIS, dropping optional CCDs. In Cycle 20, the RPS form will allow proposers to the Guest Observer programs (GOs) to specify a maximum of four required CCDs at the time of proposal submission due to thermal considerations. In addition to the four required CCDs, a GO may request that one or two optional CCDs be turned on for an observation if thermal conditions allow. If the science requires that five or six CCDs be on for an observation, the GO may work with their User Support scientist to change the CCD specification but they should be aware that this might complicate the scheduling of their observation. (See section *6.22.1 in the POG* for details.)

The mission planning depends on detailed semi-empirical thermal models of the focal plane, electronics boxes and boards, and power supplies. Much work has gone into updating these models to keep the predictions accurate, so that we can confidently operate without violating thermal limits. In early 2018, the ACIS operations team will modify the standard configuration during radiation belt passages to keep only three front-end processors (FEPs) powered instead of six. Previously, six FEPs had been powered on for radiation belt passages to keep the electronics relatively warm and to minimize temperature excursions, but given the elevated spacecraft temperatures, the ACIS electronics will be sufficiently warm with only three FEPs powered on.

While the sun has generally been very quiet—as is expected during solar minimum—there were two periods of much higher activity (mid-July and early-September of 2017) that impacted *Chandra*. Each of these were quite different, both in the energy spectrum of the particles and in the response by *Chandra*. After a few years of quiet time, this was a good opportunity for the operations team to exercise the high radiation response procedures.

In July, after an M-class solar flare, very high soft proton rates were reported by ACE (Advanced Composition Explorer), which is situated at the Sun-Earth L1 point. On-board *Chandra*, the radiation monitoring done by HRC and ACIS is most sensitive to harder particles, so while the detectors did see some elevation in particle flux, it was not high enough to trigger an autonomous radiation safing action. On the ground, the *Chandra* team examined the available data and decided not to interrupt the observing schedule. While the calculated attenuated fluence at ACIS was well over the orbital limit from this storm, the annual cumulative fluence is still far below the limit given the lack of radiation storms. No adverse effects have been detected from this event.

On September 6, 2017, the sun produced the largest X-class flare in a decade, which was followed a few days later by a nearly as powerful second flare. In both these cases, the particle spectrum was very hard, and two radiation shutdowns were triggered autonomously due to high rates in the HRC anti-coincidence shield. The ACIS radiation monitor also recorded very high rates, but did not trigger a shutdown due to the timing of the rise against the observation plan. The high radiation environment was long-lived causing *Chandra* to stay shut down for a few days. Again, no adverse effects to ACIS have been detected. The strong solar storm did, however, reduce the quiescent particle background rates measured by ACIS by about 10%, in what is known as a Forbush decrease. They have since recovered to the previous levels, typical of solar minimum.

Thinking ahead into the long-term future, the ACIS team has been developing and updating a set of operations procedures to deal with potential instrument anomalies and improved cataloging of the documentation of previous anomalies in case they reoccur. In this way, the historical knowledge of the software and hardware can be captured, which is increasingly important as key personnel move on to other projects or retire.

Another project intended to facilitate long-term operation of ACIS is monitoring the EEPROM (electrically erasable programmable read-only memory) devices in the ACIS Digital Processing Assembly. This non-volatile memory was last written twenty years ago, before launch, and contains, amongst other data, the boot code for the ACIS digital processors. The long lifetime of *Chandra* means there is little comparable data on the expected decay rate or operational lifetime of these specific devices. Starting in 2016, the ACIS team has done a monthly check of the active EEPROM, comparing the checksum of the actual contents to the expected value to identify potential bad memory locations. To date, these checksums have been identical, indicating that the contents of the active EEPROM are unchanged since before launch and free of bad memory locations. The portion of the EEPROM memory that is considered critical is actually fairly small, so any potential future bad memory locations will not necessarily require any changes in operations procedures. In the event that degradation impedes the normal function of the EEPROM, additional procedures to patch potential bad memory locations or to switch to the backup EEPROM are currently under development. ■